

ON THE CHEMICAL CONSTITUTION
OF THE
ENSISHEIM, MAUERKIRCHEN, SHERGOTTY
AND MUDDOOR
METEORIC STONES.

INAUGURAL - DISSERTATION
FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY
AT THE
GEORGIA AUGUSTA UNIVERSITY,
GÖTTINGEN,
BY
FRANK CROOK
OF BALTIMORE. U S. A.



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Introduction.

The falling of masses of stone and iron from the heavens to our planet, observed as early as 600 B. C. has made the greatest impression upon the human mind. Many of the nations of antiquity, the Phoenicians, Grecians, Romans and others, called them holy stones or Baetylien, and regarding them as symbolical of the mother of the Gods, paid them the most marked veneration; and, as we learn from the old historians and antique collections, preserved them in their temples, and carried them in their triumphal processions.

During the greater part of the past century, indeed, almost until the beginning of the present, the fact that masses of stone and iron fall to us from the heavens, was doubted and denied. Scientific men looked upon the matter as fraught with superstition, and deemed it unworthy of their consideration. Chaldni was the first to admit of the facts of the phenomenon and commence the labor of investigation, and he met

with much opposition; his opinions were looked upon as foolish and absurd, and he with his small band of followers derided and ridiculed. But in 1803, when the celebrated shower of nearly 3000 stones fell in l'Aigle in Normandy, the subject received new attention. The French National Institute appointed the well known physicist Biot, to make observations and study the fall; at the same time many of the learned devoted their study to this subject, and it was not long before the works of Izarn ¹⁾, Howard ²⁾ and Chaldni ³⁾ appeared, in which, all known concerning meteorites up to date was contained. More recently Berzelius, G. Rose and Cordier have done much to the furtherance of our knowledge of these wanderers in space, yet, much remains to be done before we can become fully acquainted with their natural history. Now, however, everyone will at least admit of the facts of the phenomena, if not adhere to one or the other of the many theories concerning their origin.

These masses of stone or iron coming to us from the regions of space, are called aerolites by those who seek for their origin in our atmosphere, moonstones by those who hold to be of electrical or vulcanic origin, but usually, meteoric iron or stone, or, with a common

1) Des pierres tombées du ciel ou Lithologue atmospherique.

2) Experiments and observations on certain stony metalline substances which, at different times are said to have fallen on the earth.

3) Ueber Feuer-Meteor, und über die mit denselben herabgefallenen Massen.

name meteorites, because they appear in the heavens as meteors or fire balls, from which, more frequently stone, but sometimes wonderful blocks of iron are precipitated to the earth with violent crackling and detonation; in many cases they have been found still warm and smelling of Sulphur.

Much labor has been expended by scientific men in endeavouring to answer the questions, whence come the meteorites, what is their origin. Because their nature in general is similar to that of our eruptive rocks, some have supposed them to be of volcanic origin. But although generally similar, a deeper study of their mode of occurrence, and of the manner of combination of the elements, makes us aware of generic differences. Meteorites contain constituents not occurring in the volcanic rocks, and have mineralogical and chemical qualities altogether peculiar to themselves; that they are of volcanic origin implies, that the metallic iron contained in them is the result of some chemical action which has taken place in the earth, but what kind of action could it have been? It is difficult to think of any possible manner in which the ignoble, easily oxidizable metals could either have been formed, or preserved in their purity in the depths of our earth. The rocks indicate no condition without vapor of water and the gaseous veil, neither do we learn from them of processes of hindered oxidation or reduction, nor of any condition or state, in which oxidation of metallic iron could not have taken place. This theory was advanced and supported by De Luc.

It was first mentioned by Albers, that they might come from lunar volcanoes, and La Place afterwards demonstrated the possibility. This theory allows of the explanation of many of the indications given by meteorites as to the nature of their native place. The moon, destitute of water and an atmosphere, without vegetation, and appearing to be made up entirely of volcanic and plutonic masses, certainly affords no condition favorable to oxidation, and also, the outward appearance of the stones, their approaching spherical form, and the rind or crust with which they are always coated, could result from the pressure and heat occasioned by their rapid fall through the atmosphere. The moon, also on account of its want of an atmosphere, would offer less resistance to particles separating from its surface than the earth. Objections however have been raised against this theory. It seems to me the principal one is, that the earth, after having received such additions of matter, must change its position in space, and deviate from its primary orbit, and that also the moon, by its loss of matter, would be likewise effected, and thereby, discord and variance replace the harmony and stability of the planetary system. The weight of the meteoric matter falling on the earth is not so inconsiderable as might be at first supposed. During the 60 years from 1803 to 1862, the weight of observed and found meteorites alone amounted to 3111,5 Kilogrm. ¹⁾ and the weight of the unobserved and unfound would probably have

¹⁾ Archiv für die Naturkunde Bd. II. S. 496.

greatly increased the number. It indeed seems that such additions of matter coming to the earth, would at least in the process of time influence the wonderful regularity of the planetary motions, if not cause immediate disturbance in the regions of space. But despite all the matter which has been conveyed into our atmosphere and to our earth by meteors and meteorites, yet, as La Place's calculation of the days length since the time of Hipparchus shows, not the slightest disturbance or irregularity has taken place in the earth's motion from Hipparchus' time to the present.

Several other theories have been advanced as to the origin of meteorites, viz: that they have their origin in our atmosphere, „that the materials, in a very finely divided or gaseous state, are elevated to the higher portions of our atmosphere, where they are sustained by magneto electric forces, and that a disturbance in those regions produces a meteoric fall;“ that they are the fragments of planets formerly existing; that they are the remnants of cosmotic materials employed in the formation of worlds etc.

Meteorites fall more frequently than is generally supposed. Nearly every year two or three falls are recorded, and these are only such as happen to be observed on the small part of the earth's surface inhabited by enlightened people. Many must fall in the ocean, and in forests, or in districts where there is no one at hand to observe them. Freiherr von Reichenbach gives

the following calculation: ¹⁾ assuming that annually during the day, two meteoric falls are observed, and the stones found; that three times as many are observed but not found; twice as many neither observed or found; in total 12. Doubling the number, because as many falls take place during the night as during the day, hence 24; because $\frac{3}{4}$ of the surface of the earth is covered by water, 4 times the number = 96. Finally, because meteorites have only been known to fall in England, France etc., together having an area equal only to the .47 part of that of the entire dry land, $47 \times 96 = 4500$ will be the number expressing the number of falls annually. Dividing this number by 365, it is seen, that for every day of the year there are 12 meteoric falls, or one for every 770,000 sq. mi. of surface. There were 91 meteoric falls in Europe between the years 1803 and 1864, and of these 22 were observed in France; assuming the number of falls proportional to the area ²⁾, and doubling for the night etc., we receive nearly 4000 falls for the whole surface of the earth annually.

From these results it is seen, that meteorites fall more frequently than is generally believed; 12 falls daily, 4500 yearly, seem enough to cause the phenomenon not to be considered as an occurrence so rare.

The falling of meteorites is attended with certain phenomena. At first a luminous point is seen, which

¹⁾ Poggendorfs Ann. B. 105. S. 551.

²⁾ And also that two falls take place daily.

gradually becomes larger, diffuses more or less light, and appears to draw a tail or misty radiance behind it. The meteorite telescopically observed by J. Schmidt ¹⁾ on Oct. 18. 1863, (not as yet however certainly determined whether it was a meteorite or meteor) appeared at first as a slowly moving spark, and gradually increased in size. During the third and and fourth second it evolved a green light and assumed the brilliancy of Sirius. With wonderful brilliancy, and a beautiful green light, it continued on its way, and at the end of the seventh second had reached considerable size. Finally, after separating into three or four dull red fragments, it sank and silently extinguished.

The noise or detonation heard during the fall of meteorites, and caused by the concussion of the atmosphere, varies with the velocity, size, and density of the stone, as well as with the depth and density of the condensed column of air. The detonation is heard sometimes before, sometimes after, and during the fall. Altogether without detonation no fall has taken place, but in one however ²⁾, the noise was not louder than that of clattering carriage wheels. Sometimes the noise is like thunder, or the discharge of heavy artillery, and sometimes like the rattling of musketry. The stone is burst into many fragments, and these bury themselves in the earth.

Mineralogically meteorites are divided into two

¹⁾ Archiv für Naturkunde B. III. S. 509.

²⁾ St. Denis-Westren in Belgien 1855.

classes: meteoric iron and meteoric stone. The former consists principally of Iron and Nickel, with small quantities of Cobalt and Phosphorus. Although meteoric iron has not often been observed to fall, yet very frequently masses have been found and recognized as being of meteoric origin; this meteoric iron possesses many characteristics and unmistakable peculiarities, which allow of almost immediate recognition by the chemist or mineralogist. The Widmannstaettian structure or the figures resulting from the etching of a polished face, is one of the most unmistakable proofs, as to the identity of supposed meteoric iron.

The meteoric stones, by far the more numerous, are mixtures or aggregates of minerals, principally silicates. The ground mass is sometimes hard and solid, sometimes quite loose and friable. The color varies from a light ash grey, to a grayish black. The iron is in variable quantity. We have cases where masses have fallen, consisting of one piece of iron, only the cavities of which were filled with the silicate. Others consist more of the earthy mass, with less iron, and being less cohesive, are burst by the heat caused by their rapid passage through the air; these latter are always coated with a crust or rind. Very often the meteoric stones present a chondritic or bally structure. The balls occur in the ground mass similar to those in many of the red porphyries, and generally are not larger than small shot, and uniformly rounded. Their surface is rough and even glandulous; in fracture they are sometimes

uneven, sometimes radiated. Their color is like that of the ground mass.

The following elements have been recognized in meteoric stones, viz:

1. Aluminium	7. Silicium	13. Nickel
2. Calcium	8. Carbon	14. Phosphorus
3. Chromium	9. Copper	15. Oxygen
4. Iron	10. Magnesium	16. Sulphur
5. Kalium	11. Manganese	17. Titanium
6. Kobalt	12. Sodium	18. Tin

Antimony, Arsenic, Lead and Chlorine have in one or two cases been detected, but were probably no constituents of the original meteorite.

In nearly all cases the meteoric stones have been found to contain at least a small quantity of the magnetic compound, Iron, Nickel, Cobalt and Phosphorus. It generally occurs in globules, varying perhaps from the size of a pea to almost imperceptible particles, which are disseminated through the mass and have a bright lustre. Schreibersite, or Phosphuret of Nickel and Iron, occurs here and there in the metallic mass as small crystals, which remain undissolved on treatment with acid, and appear of a steel gray or brownish color. Berzelius ¹⁾ regards the Widmannstaettian figures due to these impurities in the Iron, but especially to a chemical compound of Iron and Nickel, which is therein contained, and being more difficultly soluble than the Iron, remains behind on treatment with acid.

¹⁾ Berzelius Jahresbericht XV. 233.

Rammelsberg ¹⁾ thinks it more probable that the metals are uniformly alloyed, and that the figures result from the difficultly soluble Phosphorus compound (Schreibersite).

The silicates form the greater part of the meteoric mass. Their structure is often granular, showing a decided approach to crystallization; in several cases single faces have been observed, and once a crystal well enough developed to allow of description was found by G. Rose ²⁾. The results of many chemical analyses, as well as the general appearance, show the part decomposable by acid to be a silicate of the same chemical constitution as Olivine, since the ratio of the Oxygen of the base and acid is as 1 : 1; in many cases the Olivine has been observed under the microscope. It occurs in the crystalline and granular form. The crystals are often perfectly transparent, sometimes yellowish green and have a glassy glance. The meteoric Olivine is infusible before the blow pipe ³⁾, and either does not change at all, or only assumes a darker color.

The undecomposable silicate, from the ratio of Oxygen in acid and base, does not allow of the determination of its mineralogical character, since several minerals are indicated. Berzelius ⁴⁾ thought the insoluble part could be considered as consisting of an Augitic,

¹⁾ Rammelsberg Mineralchemie S. 949.

²⁾ Rammelsberg Mineralchemie S. 946.

³⁾ Rammelsberg Mineralchemie S. 940.

⁴⁾ Jahresbericht XV S. 231.

and a Leucitic mineral, in which latter, a part of the Soda and Potash are replaced by Lime and Magnesia. The never failing presence of Soda and Potassa, seem to indicate a Feldspathic mineral, and the occurrence of protoxyd of Iron, Lime and Magnesia render the presence of a mineral of the Augitic group probable.

Sulphuret of Iron occurs in most of the stones and is often disseminated in small dark particles. At first it was supposed to be pyrites. Later Berzelius expressed the opinion that it was protosulphuret, which Rammelsberg ¹⁾ has fully confirmed.

Chromic Iron is frequently found in the stones, but only in small quantity. It is sometimes crystallized but more often granular. Tinoxid is sometimes found with the Chromium.

The most interesting element occurring in meteorites is Carbon. It is sometimes in the form of Graphits, sometimes in the finely divided form. Berzelius in speaking of the nature of the organic matter he found in the Alais M. says ²⁾: water extracted from the stone nothing organic. By dry distillation Carbonic acid, water, and a grayish black sublimate were obtained, but no inflammable oil, no Carbaretted-hydrogen, in a word, the substance was not of the same nature as our humus. The residue was coaled and black. The sublimate, on being heated in Oxygengas, gave no trace of Carbonic acid or water, but changed itself into a

¹⁾ Rammelsberg Mineralchemie S. 948.

²⁾ Berzelius Jahresbericht XV 236.

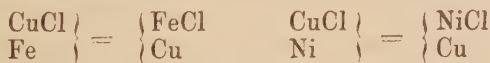
white, and volatile body, which when treated with water dissolved without imparting acidity to the latter, nor was the solution precipitated by Nitrate of Silver. What this substance is I do not know, to me it is totally unknown. Could it be an elementary substance originally not belonging to our earth? To answer this question affirmatively might be overhasty."

Recently the nature of this organic material has been more definitely ascertained. In the stones from Kaba and Bokkeveld Prof. Wöhler found, together with amorphous Carbon, a substance which could be extracted by Alcohol and which consisted of a semi-liquid and crystalline part, and at a low red heat was decomposed with the separation of Carbon and the formation of an oil of bituminous odor. When he subjected the latter stone to dry distillation (after previous drying at 120°) 10.5% of water went over, which had a bituminous odor and was milky from an oil, and so alkaline from Carbonate of Ammonia that Carbonic acid was liberated by Chlorhydric acid. Cloëz found also in the stone from Orgueil 8% of water, which was only driven off at a temperature above 200° . From these results it would seem that there, where the meteorites come from water, ammonia and organic matter exist and probably also, organisms.

Before proceeding with the regular analyses of the meteoric stones I have examined, I shall briefly describe the processes and methods adopted. The analysis of meteoric stones is one of the more complicated of analytical chemistry, and to ensure accuracy, many special precautions and much care is necessary.

Methods of Analysis.

The exact determination of the chemical constitution of stone meteorites, which the preliminary examination generally shows to be composed of Sulphuret of Iron, Nickel-Iron, Schreibersite, decomposable Magnesia and protoxyd of Iron, and undecomposable Alumina-Alkali silicates, has its peculiar difficulties. The separation of the metallic part by means of the magnet is imperfect and tedious; a little of the finely divided silicate will adhere to the uneven surface of the Iron, and the very small particles of Iron, covered and concealed by the silicate, remain uninfluenced by the magnet. The determination of the Iron and Sulphur by direct treatment with Chlorhydric acid and collecting the Hydrogen and Sulphuretted-hydrogen gas, has not in all cases given satisfactory results. The method based upon the reaction of the Chlorides of Copper, Mercury, and Silver on metallic Iron, allows of its determination with the desirable accuracy and elegance. If Iron, Nickel, or Nickel-Iron is digested in a stream of Hydrogen with either of these Chlorides, the following well known reaction takes place:



The meteoric metals precipitate like equivalents of the non meteoric metals, and pass themselves into solution as protochlorids. I have used Chloride of Copper for this determination, and after the decomposition was fully effected, determined the Sulphur by fusing the residue with Carbonated Alkali and Saltpeter, and at the same time, made another determination of Silicic acid to control the one by Hydrofluoric acid and calculated as loss.

The analysis consists of three courses of operations.

I. Determination of the Iron by Chloride of Copper, and of the Sulphur and Phosphorus.

The finely pulverized meteorite was put into an air tight shutting cylinder, and over it a tolerably concentrated solution of Chloride of Copper poured, and with this solution the cylinder filled, and with frequent shaking allowed to stand several days. The reduction of Copper immediately took place but it gradually disappeared being dissolved in the excess of Chloride as Subchloride. After the decomposition was fully effected, the solution was rapidly filtered and the residue washed, the filter always being kept full. The Copper was precipitated by Sulphuretted hydrogen, the Iron after oxidation separated from the Nickel and Cobalt by Succinate of Ammonia, and the precipitate dried and weighed. The washed residue was fused with Carbonated Alkali and Saltpeter, the solution evaporated to dryness, again treated with acid and

water, and the Sulphuric, and Silicic acids determined in the usual way. To determine the Phosphorus always in small quantity, but still so characteristic of meteorites, a separate portion was oxidized by Aqua Regia, the Iron precipitated by Succinate of Ammonia, the precipitate fused with Carbonate of Soda, and in the aqueous solution the Phos. acid precipitated as Phosphate Ammonia-Magnesia.

II. Analysis of the part decomposable by acids.

The finely divided powder was treated in a porcelain dish with Chlorhydric acid and a few drops of Nitric acid, and the whole evaporated to dryness over the water bath, with continual stirring, until the lumps were broken up and the mass perfectly dry; then treated with acid and water, and filtered and washed. After the washing was completed, the residue, in small portions at a time, was put into a dish containing a solution of boiling Carbonate of Soda, whereby the Silica belonging to the dissolved bases was separated from the undecomposable part. The alkaline solution, on being evaporated and treated with acid, leaves the Silica undissolved. The acid solution, after most of its acid had been removed by concentration, was treated with Succinate of Ammonia, and the precipitate dried, burnt and weighed. The precipitate contains oxyd of Iron with Alumina and traces of Phos. acid. It was dissolved in

Chlorhydric acid, and, after the addition of Tartaric acid, the Iron precipitated as Sulphide, and the Alumina calculated as loss. The Phos. acid having been determined in I. was deducted from the weight of the precipitate.

In the Succinic acid filtrate the Nickel, Cobalt and Manganese were precipitated as Sulphides, the precipitate oxidized by Nitric acid, and again precipitated as oxides by Potassa. This precipitate was fused with Carbonate of Soda and Sulphur. The Sulphides of Nickel and Cobalt so received, are more insoluble than when freshly precipitated, and easily allow of the separation of the Manganese by dilute acid. The Cobalt was separated from the Nickel by the Nitrite of potassa method, but in most cases, the precipitate was so considerable as to give only a slight blue color when dried and treated with Phos. salt before the blow pipe. The Nickel was precipitated as oxyd, and the Manganese as Carbonate. In the Sulphide of Nickel filtrate the Lime was precipitated by Oxalic acid; Magnesia separated from the Alkalies by Barytawater, and the latter determined in the usual way.

III. Analysis of the part undecomposable by acids.

The insoluble part, after having been separated from the gelatinous Silica by long digestion with Carbonate of Soda, was decomposed by Fluorhydric acid

and Sulphuric acid. In nearly every case a slight residue remained which proved itself to be Chrome-Iron, and was so weighed. In the Chrome-Iron residue Tin was sought for by dissolving it in acid Sulphate of Potash, and treating the solution with Hydrosulphuric acid, but in no case was even a coloration obtained. The Fluorhydric solution and residue was evaporated, again treated with Fluorhydric and Sulphuric acids, ignited to remove the excess of Sulphuric acid, and the solution treated with Succinate of Ammonia and Oxalic acid etc., as in II. and Magnesia and the alkalies determined by Baryta water and Bichloride of Platinum.

Although the treatment with Chlorhydric acid does not allow of the complete separation of the two classes of Silicates, yet it affords us some idea as to their nature.

The Ensisheim stone.

This is one of the oldest among the preserved. It fell on 17 Nov. 1492 with violent detonation. The Emperor Maximilian I. ordered the stone to be placed in the church at Ensisheim, where it remained until the French revolution. It has been frequently broken, and now there are only 40—50 Kil. remaining in the old place. For examination I had a small fragment which Prof. Wöhler gave me from the Göttingen collection.

It was without crust or rind. The ground mass is of a dark gray color and granular, somewhat approaching the chondritic structure. On examination of a polished surface under the microscope many variously formed, round to angular, larger and smaller, dark green parts appeared imbedded in the lighter mass. This dark substance does not appear crystalline but granular, with the lustre of wax, and an uneven fracture. The lighter mass is crystalline, and with the glass, yellow to brown transparent crystals can be observed, which call to mind Olivine. The Sulphide of Iron occurs finely disseminated through the mass; that it is protosulphuret the case with which the stone evolves Sul. hydr. gas when treated with acid seems to render probable.

Chemical analysis.

I. 3.500 grm. treated with Chloride of Copper gave:

.400	grm.	$\ddot{\text{Fe}}$	=	.280	grm.	Fe	=	8 ⁰ / ₁₀	Fe
.516	"	$\text{Ba}, \ddot{\text{S}}$	=				=	2.05	" S
1.245	"	$\ddot{\text{Si}}$					=	35.647	" $\ddot{\text{Si}}$
.002	"	$2\ddot{\text{Mg}}, \ddot{\text{P}}$					=	.013	" P
									from 3.425 grm.

II. 3.210 grm. gave:

(a) *soluble part.*

1.494	grm.	$\ddot{\text{Fe}}$	=	1.046	grm.	Fe	=	32.593 ⁰ / ₁₀	Fe
.623	"	$2\ddot{\text{Mg}}, \ddot{\text{P}}$					=	7	" $\ddot{\text{Mg}}$
.526	"	$\ddot{\text{Si}}$					=	16.244	" $\ddot{\text{Si}}$
.0098	"	$\ddot{\text{Al}}$					=	.307	" $\ddot{\text{Al}}$

.015	"	Ca	=	5000/0	Ca
.0502	"	Ni	=	1.230	" Ni
(b) <i>insoluble part.</i>					
.1216	gram.	Fe	=	3.410/0	Fe
.544	"	2MgP	=	6.130	" Mg
.622	"	Si	=	19.403	" Si
.064	"	Al	=	2.000	" Al
.0409	"	Ca	=	1.276	" Ca
.022	"	NaCl	=	.376	" Na
.0373	"	KPtCl ₃	=	.223	" K
.019	"	FeGr	=	.600	" FeGr
.0217	"	Mn ₃	=	210	" Mn

Hence, in 100 parts the Ensisheim stone contains:

Protosulphuret of Iron	5.642/0	}	3.592 Fe
			2. 05 S
Iron with Nickel, traces of			
Cobalt and Phosphorus	9.243 "	}	8.000 Fe
			1.230 Ni
			1.013 P
Chrome-Iron	.600 "	}	.1911 Fe
			.4089 Gr
Silicates	84.079 "		
	99.564 "		

Constitution of the Silicates.

I. *in acid soluble.*

Oxygen	Base	Oxygen	Acid
5.999	Fe 27.000		
2.797	Mg 7.000		
.142	Al .307	8.662	Si 16.244
.142	Ca .500		

II. *in acid insoluble*

Oxygen	Base	Oxygen	Acid
.756	Fe 3.410	10.347	19.403
2.448	Mg 6.130		
.932	Al 2.000		
.363	Ca 1.276		
.049	Na .376		
.033	K .223		
.047	Mn .210		

Considering first the soluble Silicate, and regarding the small quantities of Lime and Alumina as resulting from the partial decomposition of the insoluble, we have:

$$\begin{array}{l} \text{Fe } 27.000 \\ \text{Mg } 7.000 \end{array} \left. \vphantom{\begin{array}{l} \text{Fe } 27.000 \\ \text{Mg } 7.000 \end{array}} \right\} = 8.795 \text{ O, } \text{Si } 16.244 = 8.662 \text{ O}$$

or a Silicate the Oxygen in the base and acid of which, is nearly in the ratio of 1 : 1, corresponding to the formula $2\text{RO}, \text{SiO}_2$ (Olivine). The Oxygen of the base is almost always greater than it should be to exactly answer this formula, which is probably due in a great measure, to the difficulty with which the Silicic acid of the soluble part is separated from the insoluble part.

It is much more difficult to determine the nature of the undecomposable silicate. Its chemical constitution shows it not to be a single combination, but a mixture of silicates. Rammelsberg ¹⁾ has already called attention to the analogy of meteoric stones and the common doleritic lavas. In the latter Olivine also occurs, and the

¹⁾ Rammelsberg Mineralchemie S. 945.

Nickel-Iron and Sulphuret of Iron seem to be replaced by Titanic-iron and Magnetite. Labrador very probably makes up one of the constituents of the insoluble part, both because it occurs so widely in the vulcanic rocks, (Dolerite, Basalt, Lava), and because the chemical constitution has so often indicated it.

We will then first calculate the amount of Labrador in the insoluble part, and then examine the remainder, and if possible refer it to a mineral. To calculate the amount of Labrador, $(Al_2O_3, SiO_2^2 + Ro, SiO_2)$, it is only necessary to substitute twice the Oxygen of the total Alumina (2.148) in the formula $(SiO_2 : O_2 = x : 2.148)$, and we get the corresponding amount of Silicic acid; there then only remains to substitute the Lime Soda and Potassa corresponding to one equivalent of O or .358.

Silicic acid	4.023	2.148 = 6, Oxygen
Alumina	2.307	1.074 = 3, Oxygen
Lime	.766	.219
Soda	.376	} = 1, Oxygen
Potassa	.223	
	7.695	

Hence, we have 7.695% of Labrador, $R : \ddot{Al} : \ddot{S}$ being
1 : 3 : 6

the ratio of Oxygen.

Examining the remainder after deducting the Labrador:

		Oxygen	
Silicic acid	15.380	8.201	
Lime	1.016	.288	} = 3.539 Ox.
Magnesia	6.130	2.448	
Protoxyd of Iron	3.410	.756	
Protox. of Manganese	.210	.047	
	26.146		

we find it to be a mineral very nearly corresponding to Augit; the ration of its Oxygen in acid and base is as R : Si

1 : 2.15, while that of the remainder is 1 : .2.31. The excess is so small, that we can not do otherwise than consider our mineral as an Augit. Therefore the Ensisheim stone contains:

50.244%	Olivine
7.695	„ Labrador
26.146	„ Augit.

The Mauerkirchen stone.

This stone fell Nov. 20th. 1768, with explosion and was found the following morning. It weighed 19 Kil. and was broken into two pieces. In the Göttingen collection there is a fine specimen weighing 1927 grm. One of the small fragments I had for examination possessed

a partial rind which was dark brown in color and thicker than is generally found. The powder examined under the microscope shows transparent crystals and very small dark particles, which I took to be very finely divided Iron, since the Iron occurs in such small quantity as hardly to be observed with the naked eye. Sulphydric acid was evolved on treating the stone with acid.

I. 3.100 grm. treated with Chloride of Copper gave:

.130 grm.	$\ddot{\text{Fe}}$	=	30% Fe
.152 "	$\text{Ba}\ddot{\text{S}}$	=	.705 S
1.286 "	$\ddot{\text{Si}}$	=	41.532 $\ddot{\text{Si}}$

II. 3.250 grm. gave:

(a) *in soluble part.*

.785 grm.	$\ddot{\text{Fe}}$	= 550 grm. Fe	= 16.933 Fe
1.917 "	$2\text{Mg}\ddot{\text{P}}$		= 21.245 Mg
.602 "	$\ddot{\text{Si}}$		= 18.529 $\ddot{\text{Si}}$
.006 "	$\ddot{\text{Al}}$		= .205 $\ddot{\text{Al}}$
.011 "	$\dot{\text{Ca}}$		= .350 $\dot{\text{Ca}}$
.308 "	Nil		= .745 Ni

(b) *in insoluble part.*

.230 "	$\ddot{\text{Fe}}$	=	6.387 Fe
.266 "	$2\text{Mg}\ddot{\text{P}}$	=	2.957 Mg
.747 "	$\ddot{\text{Si}}$	=	23.003 $\ddot{\text{Si}}$
.048 "	$\ddot{\text{Al}}$	=	1.500 $\ddot{\text{Al}}$
.057 "	$\dot{\text{Ca}}$	=	1.765 $\dot{\text{Ca}}$
.020 "	NaCl	=	.242 Na
.024 "	PtCl_3K	=	.145 K
.023 "	$\text{Fe}\ddot{\text{Cr}}$	=	.725 $\text{Fe}\ddot{\text{Cr}}$

Hence in 100 parts, the Mauerkirchen stone contains:

Sulphuret of Iron	1.938	{ 1.233 Fe .705 S
Iron, Nickel and traces Cobalt	3.745	{ 3.000 Fe .745 Ni
Chrome-Iron	.725	{ .232 Fe .493 Cr
Silicates	92.328	
	98.736	

Constitution of the Silicates.

(a) *soluble*

Oxygen	Base
3.555	16.000 Fe
8.487	21.245 Mg
9.877	18.529 Si
.095	.205 Al
.099	.350 Ca

(b) *insoluble*

Oxygen	Base
1.417	6.387 Fe
1.179	2.957 Mg
12.266	23.003 Si
.499	1.500 Al
.503	1.765 Ca
.061	.242 Na
.022	.145 K

Proceeding in the same manner as with the Ensisheim stone we have:

$$\begin{array}{rcl} \text{Fe } 16.000 & \left. \vphantom{\begin{array}{l} \text{Fe } 16.000 \\ \text{Mg } 21.245 \end{array}} \right\} = \text{Oxygen} & \\ & 12.042 & \text{Si } 18:527 = 9.887 \\ \text{Mg } 21.245 & & \end{array}$$

In this case the oxygen of the base greatly exceeds that of the acid, but the insoluble part, as will soon be seen, contains just about the same quantity of Oxygen in the acid, over and above what is necessary to compose the Augit and Labrador as is wanting in the soluble part to form Olivine; calculating the Labrador:

$$\begin{array}{rcl} \text{Silicic acid } 2.230 & = & 1.188 \text{ O} \\ \text{Alumina } 1.705 & = & .594 \text{ " } \\ \text{Lime } .402 & = & .115 \text{ " } \\ \text{Soda } .242 & = & .061 \text{ " } \\ \text{Potassa } .145 & = & .022 \text{ " } \end{array} \left. \vphantom{\begin{array}{l} \text{Silicic acid } 2.230 \\ \text{Alumina } 1.705 \\ \text{Lime } .402 \\ \text{Soda } .242 \\ \text{Potassa } .145 \end{array}} \right\} = 198 \text{ O}$$

$$\begin{array}{c} \text{R : Al : Si} \\ 1 : 3 : 6 \end{array}$$

there remains

$$\begin{array}{rcl} \text{Silicic acid } 20.773 & = & 11.078 \text{ O} \\ \text{Magnesia } 2.957 & = & 1.179 \text{ " } \\ \text{Protox.-Iron } 6.387 & = & 1.4417 \text{ " } \\ \text{Lime } 1.713 & = & .407 \text{ " } \end{array} \left. \vphantom{\begin{array}{l} \text{Silicic acid } 20.773 \\ \text{Magnesia } 2.957 \\ \text{Protox.-Iron } 6.387 \\ \text{Lime } 1.713 \end{array}} \right\} = 3.003 \text{ O}$$

which does not bear the ratio of the acid and basic Oxygen of Augit. If we however diminish the Oxygen of the bases of the soluble part so, that the Olivine formula may be answered, (subtract 2.155) and add this number to the bases of the insoluble part, then the ratio of oxygen in the acid and base of the insoluble part

will be exactly as 1 : 2.15. The remaining of the silica of the soluble bases with that of the in soluble part is probably due to insufficient digestion in Carbonate of Soda. To dissolve out all the silica much time and patience is necessary; on filtering, the solution being thereby somewhat cooled, it separates out, and adheres to the sides of the filter, from which it is almost impossible to remove or dissolve it. We conclude the Mauerkirchen to contain:

55.774% Olivine

4.727% Labrador

31.830% Augit.

The Shergotty stone.

This stone fell at Shergotty near Gya in India, on August 26. 1865. As to the phenomena of the fall I have not been able to learn anything. For analysis I had about 6 grammes in the form of coarse powder. This specimen was sent by Dr. Hörnes from the Vienna cabinet to Prof. Wöhler for analysis. In the larger lumps bright shining Nickel-Iron could easily be seen, and under the microscope transparent and yellowish, green to brown crystals could be observed. It was with difficulty pulverized, it being necessary to remove the Iron with the magnet; after the silicate was sufficiently pulverized the Iron was carefully replaced.

I. 3.115 grm. gave:

.361 grm.	$\ddot{\text{Fe}}$	=	8.143% $\ddot{\text{Fe}}$
1.126 "	"	=	36.210% $\ddot{\text{Si}}$

II. 3.00 grm. gave:

(a) *soluble part.*

.645 grm.	$\ddot{\text{Fe}}$	=	19.020% $\ddot{\text{Fe}}$
1.342 "	$2\ddot{\text{Mg}}\ddot{\text{P}}$	=	16.112 " $\ddot{\text{Mg}}$
.003 "	$\ddot{\text{Al}}$	=	.141 " $\ddot{\text{Al}}$
.483 "	$\ddot{\text{Si}}$	=	16.101 " $\ddot{\text{Si}}$
.049 "	$\ddot{\text{Ni}}$	=	1.300 " $\ddot{\text{Ni}}$

(b) *insoluble part.*

.267 grm.	$\ddot{\text{Fe}}$	=	8.021% $\ddot{\text{Fe}}$
.666 "	$2\ddot{\text{Mg}}\ddot{\text{P}}$	=	8.002 " $\ddot{\text{Mg}}$
.051 "	$\ddot{\text{Al}}$	=	1.730 " $\ddot{\text{Al}}$
.603 "	$\ddot{\text{Si}}$	=	20.110 " $\ddot{\text{Si}}$
.012 "	NaCl	=	.223 " $\ddot{\text{Na}}$
.012 "	$\ddot{\text{Ca}}$	=	.435 " $\ddot{\text{Ca}}$
.017 "	KPtCl_3	=	.109 " $\ddot{\text{K}}$
.009 "	$\ddot{\text{Fe}}\ddot{\text{Cr}}$	=	.321 " $\ddot{\text{Fe}}\ddot{\text{Cr}}$

Hence the Shergotty stone in 100 pts. contains:

Iron and Nickel with

traces of S. P. and Co. 9.443 $\left\{ \begin{array}{l} 8.143 \ddot{\text{Fe}} \\ 1.300 \ddot{\text{Ni}} \end{array} \right.$

Chrome-Iron .321 $\left\{ \begin{array}{l} .084 \ddot{\text{Fe}} \\ .237 \ddot{\text{Cr}} \end{array} \right.$

Silicates 90.014

99.778

Constitution of the Silicate.

(a) *soluble part.*

Oxygen	
4.224	19.020 Fe
6.432	16.112 Mg
.064	.141 Al
8.586	16.101 Si

(b) *insoluble part.*

Oxygen	
1.781	8.021 Fe
3.197	8.002 Mg
.805	1.730 Al
10.721	20.110 Si
.123	.435 Ca
.056	.223 Na
.017	.109 KO

The Labrador

Silicic acid	3.022	1.610
Alumina	1.871	.805
Lime	.435	.268
Soda	.216	
Potassa	.073	

and

$$\begin{array}{l} R : \text{Al} : \text{Si} \\ 1 : 3 : 6 \end{array}$$

The Rest

Silicic acid	17.088	9.111
Protoxydiron	8.021	1.781
Magnesia	8.002	3.197
Lime	.069	.216

compose the insoluble part and

$$\begin{array}{rcl}
 19.020 \text{ Fe} & \left\{ & \text{Si} \\
 & 10.656 \text{ O} & 16.101 = 8.586 \text{ O} \\
 6.432 \text{ Mg} & \left. \right\} &
 \end{array}$$

compose the soluble part.

The results are about the same as in the last analysis: too much Silica remains with the insoluble, and too little with the soluble, to determine them as Olivine and Augit.

The Muddoor stone.

This stone fell in India on the 21st. Sept. 1865. The specimen for analysis was also sent to Prof. Wöhler by Dr. Hörnes from the Vienna Cabinet. The stone has a gray appearance and the small fragments I had, were without rind. Disseminated through the mass Nickel-Iron can be seen, and under the microscope, as in the former case, transparent and brownish crystals were observed; with Hydrochloric acid Sulphydric acid was freely evolved.

I. 3.140 grm. treated with Chloride of Copper gave:

.356 grm.	Fe	=	7.941% Fe
.304	BuS	=	1.543 „ S
1.198	Si	=	36.256 „ Si

(a) *soluble part.*

3.141 grm. gave:

1.525 grm.	$2\ddot{\text{Mg}}\ddot{\text{P}}$	=	16.341% $\ddot{\text{Mg}}$
.862 "	$\ddot{\text{Fe}}$	=	19.227 " $\ddot{\text{Fe}}$
.472 "	$\ddot{\text{Si}}$	=	16.056 " $\ddot{\text{Si}}$
.046 "	$\ddot{\text{Ni}}$	=	1.162 " $\ddot{\text{Ni}}$
.016 "	$\ddot{\text{Ca}}$	=	.530 " $\ddot{\text{Ca}}$
.006 "	$\ddot{\text{Al}}$	=	.198 " $\ddot{\text{Al}}$

(b) *insoluble part.*

.241 grm.	$\ddot{\text{Fe}}$	=	6.930% $\ddot{\text{Fe}}$
.971 "	$2\ddot{\text{Mg}}\ddot{\text{P}}$	=	11.142 " $\ddot{\text{Mg}}$
.634 "	$\ddot{\text{Si}}$	=	20.200 " $\ddot{\text{Si}}$
.075 "	$\ddot{\text{Al}}$	=	2.430 " $\ddot{\text{Al}}$
.008 "	$\ddot{\text{Ca}}$	=	.280 " $\ddot{\text{Ca}}$
.046 "	KPtCl_3	=	.285 " $\ddot{\text{K}}$
.019 "	NaCl	=	.330 " $\ddot{\text{Na}}$
.007 "	$\ddot{\text{Fe}}\ddot{\text{Cr}}$	=	.239 " $\ddot{\text{Fe}}\ddot{\text{Cr}}$

Hence in 100 parts the Muddoor stone contains:

Protosulphuret of Iron	4.293 "	{	2.750 $\ddot{\text{Fe}}$
			1.543 S
Iron and Nickel			
with traces of Co.	9.103 "	{	7.941 $\ddot{\text{Fe}}$
			1.162 $\ddot{\text{Ni}}$
Chromic-Iron	.239 "	{	.079 $\ddot{\text{Fe}}$
			.158 $\ddot{\text{Cr}}$
Silicates	85.683 "		
	99.318 "		

Constitution of the Silicates.

I. *in acid soluble.*

16.341%	Mg	=	6.529	O
10.961	" Fe	=	2.435	"
.530	" Ca	=	.150	"
.198	" Al	=	.090	"
16.056	" Si	=	8.562	"

II. *in acid insoluble.*

6.930%	Fe	=	1.535	O
11.142	" Mg	=	4.450	"
20.200	" Si	=	10.766	"
2.230	" Al	=	1.128	"
.280	" Ca	=	.079	"
.285	" K	=	.046	"
.330	" Na	=	.084	"

By observing the Oxygen in the acid and base of the soluble part it is found to be nearly in the ratio of 1 : 1 corresponding to Olivine. The insoluble part, as a similar calculation to that made in determining the mineralogical constitution of the Ensisheim stone shows, nearly corresponds in constitution to Labrador and Augit.

From the results it is seen, that in every case a mineral of the chemical constitution of Olivine consti-

tutes the soluble part, and although the chemical constitution of the insoluble part does not in all cases exactly correspond to, yet it strongly indicates an Augitic and Feldspathic mineral.
